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ELECTRON MICROSCOPIC OBSERVATION OF CHRONIC PULMONARY EMPHYSEMA

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Chronic pulmonary emphysema is one of the most common chronic diseases of the lung. It may be defined as a condition of the lung characterized by abnormal increase in size of the air space distal to the terminal bronchioles either from dilatation or from destruction of their walls. Until recently much attention has been paid to the morphological changes of the alveolar walls and the disturbances of respiratory function in this disease^{3,8)}, but the relationship between the morphological changes and the functional disturbances of the lung has not yet been clarified.

It is now possible to demonstrate the fine structure of the alveolar walls in the normal and the diseased lung with electron microscopes. This paper reports observations of the fine structure of the alveolar walls in the pulmonary emphysema, and collates the findings with the results of function tests.

I. *Materials and Methods*

Materials used for this study were normal and emphysematous human lung tissues which were removed immediately after thoracotomy. Normal lung tissues and experimentally produced compensatory emphysema of dogs were also used in the present investigation.

Small blocks of tissues about 1 cubic millimeter were fixed in 1 per cent osmium tetroxide fixative adjusted at pH 7.4 and made isotonic with phosphate buffer containing sucrose. The duration of the fixation was from 30 to 60 minutes. After several washings in phosphate buffer or water, tissues were dehydrated in ascending concentrations of alcohol solutions and finally embedded in a 6:4 or 5:5 butyl-methyl methacrylate mixture. The sections were cut on the Hitachi ultra-microtome model UM-3 and analyzed in the Hitachi electron microscope model HS-6.

II. Results

A. *Fine Structure of the Alveolar Wall in the Normal Lung*

The alveolar wall is covered continuously with two kinds of epithelial cells as described in the previous publication⁵⁾. One is the alveolar epithelial cell and the other is what we call the alveolar wall cell. The former thickens in the area of the nucleus and attenuates to form a complete covering for the alveolar wall.

The endothelium of the blood capillary in the alveolar wall extends as a thin membrane with an average thickness of about $0.1\text{--}0.2\mu$, down to the minimum of approximately 0.01μ , and completely lines the lumen of the alveolar capillary. "Basement membrane" can be seen as underlying elements of the alveolar epithelium and of the capillary endothelium. It appears as a structureless layer with the thickness about 200 \AA in the thinnest portion.

The "blood-air-barrier" or "blood-air-pathway" consists of alveolar epithelium, capillary endothelium, both basement membranes and the intermediate layer between both basement membranes as shown in Fig. 1, and it reaches in places the extreme thinness of approximately 0.1μ .

In addition to the previously mentioned cells, many collagen fibers, elastic fibers, smooth muscles and some mesenchymal cells are present within the alveolar septum.

B. *Fine Structure of the Alveolar Wall in the Emphysematous Lung*

Chronic pulmonary emphysema has commonly been classified as follows^{6,7)}:

- | | |
|---|---|
| { | obstructive emphysema (hypertrophic emphysema, essential
emphysema, substantial emphysema) |
| | non-obstructive emphysema |
| { | senile emphysema (atrophic emphysema, postural
emphysema) |
| | compensatory emphysema |

The authors examined these three types of the chronic pulmonary emphysema from the human being and from tissues of experimentally produced compensatory emphysema of the dog. Obstructive emphysema can be distinguished histologically from non-obstructive emphysema by the existence of obstructions in the bronchioles. However, morphological changes of the alveolar area exclusive of the bronchioles look alike in every type of chronic pulmonary emphysema.

In the normal lung, the most conspicuous feature of the alveolar wall is a

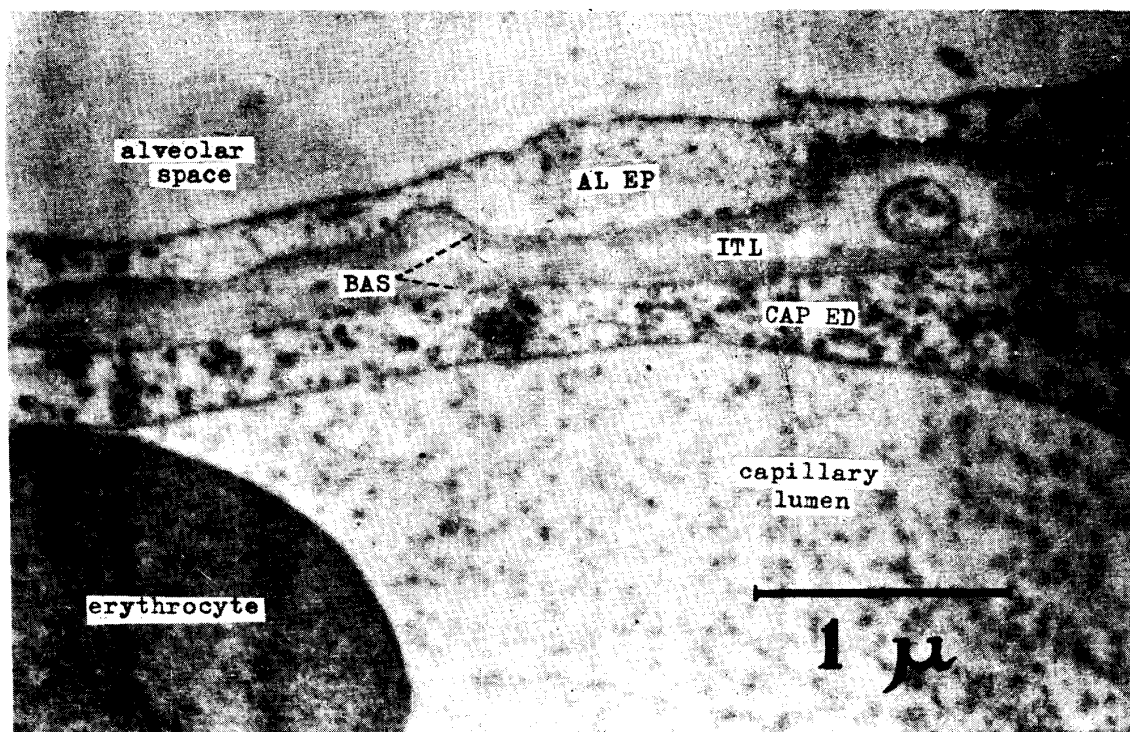


Fig. 1. "Blood-air-barrier" in the normal lung.
 AL EP: alveolar epithelium, CAP ED: capillary endothelium,
 BAS: basement membrane, ITL: intermediate layer.

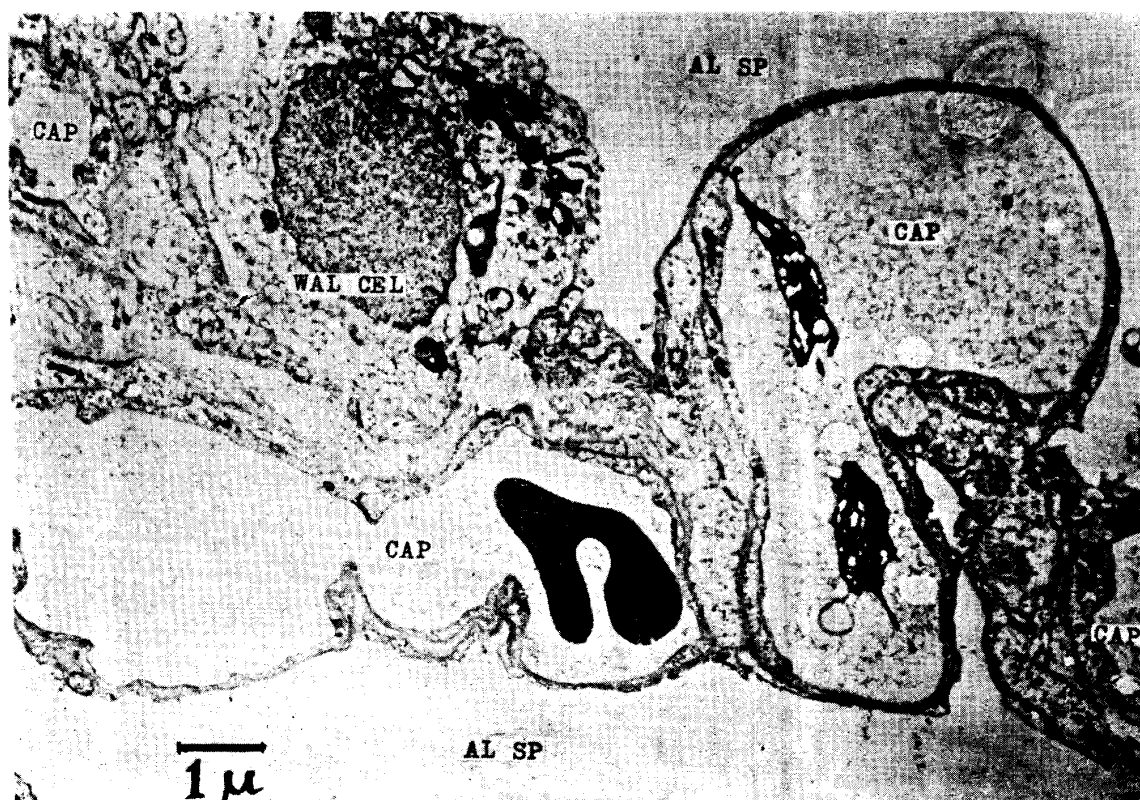


Fig. 2. Alveolar wall in the normal lung.
 AL SP: alveolar space, CAP: capillary lumen,
 WAL CEL: alveolar wall cell.

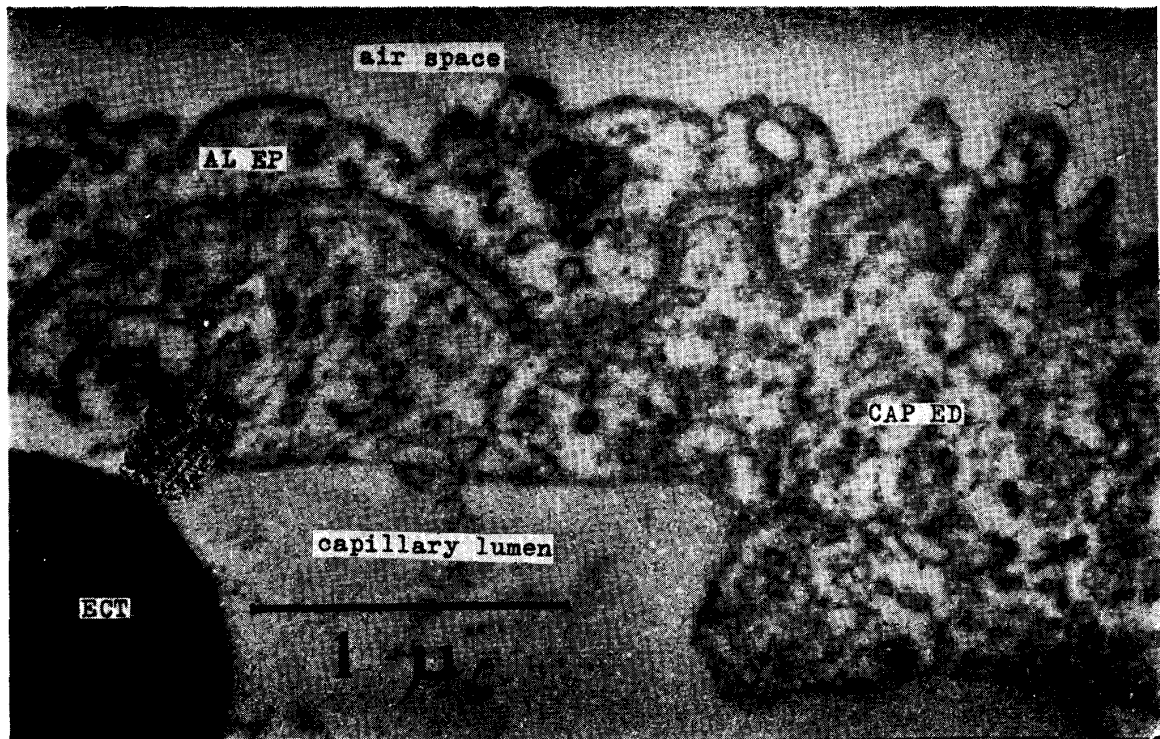


Fig. 3. "Blood-air-barrier" in the emphysematous lung.
 AL EP: alveolar epithelium, CAP ED: capillary endothelium, ECT: erythrocyte.

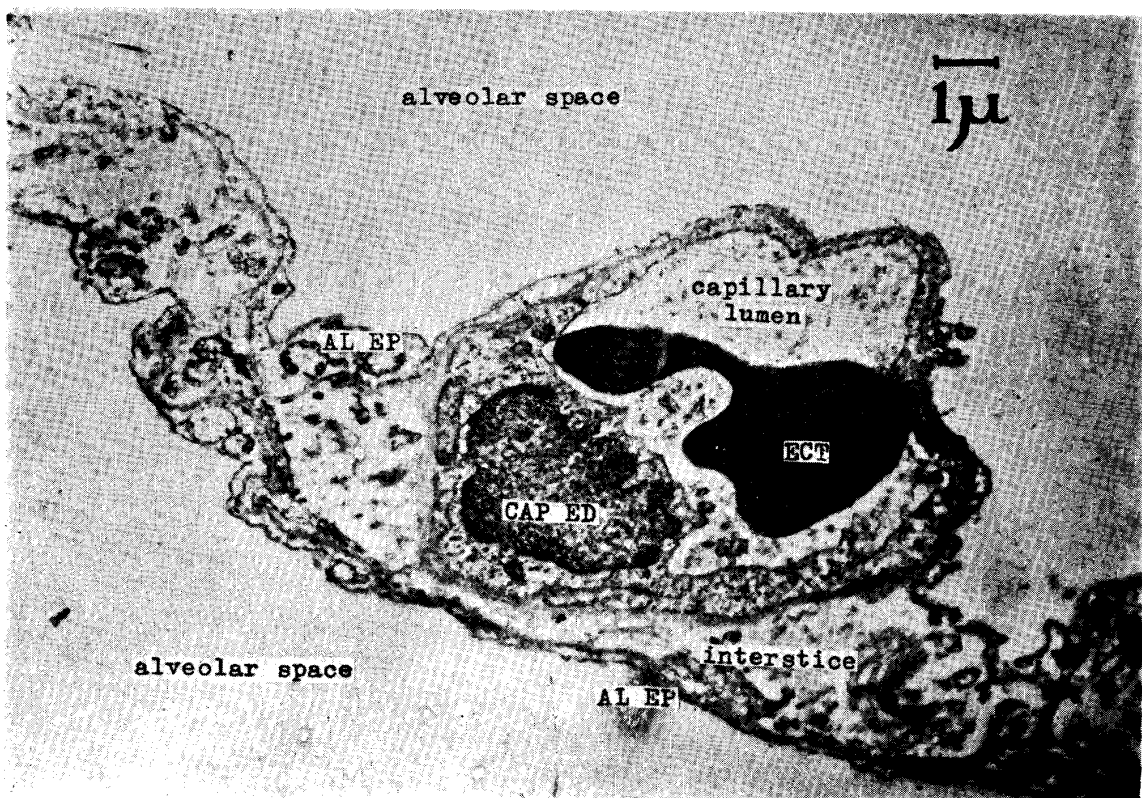


Fig. 4. Alveolar wall in the emphysematous lung.
 AL EP: alveolar epithelial cell, CAP ED: capillary endothelial cell, ECT: erythrocyte.

dense network of capillaries. These capillaries are so situated that the greater portion of their surface faces toward the alveolar air space as shown in Fig. 2. In the emphysematous lung, the alveolar capillaries are fewer than in the normal lung and the endothelial cells are so thick as shown in Fig. 3 that the diameter of their lumen is usually much less than the normal size. Therefore, the interstitial tissues are predominant in the emphysematous lung.

In many sites of the emphysematous lung the alveolar septa become thin as shown in Fig. 4 owing to the stretching.

The authors made a survey of the proportion of the three major elements in the alveolar septum, viz. epithelial tissue, interstitial tissue and capillaries. The electron micrograms of the same magnification were enlarged on printing papers and the proportion of these three elements were estimated. Tables 1 and 2 present the results of this survey and it is clear that in the emphysematous lung the interstitial tissues occupy a greater proportion than the capillaries do as compared to the normal lung.

In the emphysematous lung the endothelial cell of the alveolar capillary is thickened as shown in Fig. 3 and the ratio of the capillary lumen to the capillary endothelium decreases as shown in Tables 1 and 2. The basement membranes of the alveolar epithelium and the capillary endothelium are often seen to be undulated in the emphysematous lung.

Table 1. Proportion of epithelial tissue, interstitial tissue and capillaries in the alveolar septum (human being).

	epithelial tissue	alveolar capillaries	interstitial tissue	ratio of the capillary lumen to the capillary endothelium
normal lung	225 (16.1%)	439 (31.4%)	733 (52.5%)	40.7 : 100
emphysematous lung	268 (13.5%)	409 (20.6%)	1308 (65.9%)	56.1 : 100

Table 2. Proportion of epithelial tissue, interstitial tissue and capillaries in the alveolar septum (dog).

	epithelial tissue	alveolar capillaries	interstitial tissue	ratio of the capillary lumen to the capillary endothelium
normal lung	102 (19.0%)	286 (53.2%)	150 (27.8%)	31.2 : 100
emphysematous lung	176 (17.5%)	384 (38.2%)	445 (44.3%)	59.3 : 100

III. Discussion and Summary

Chronic pulmonary emphysema has been roughly divided into two types, viz. obstructive and non-obstructive emphysema according to whether obstructions in the bronchioles are present or not^{6,7)}. However, the authors could not find any differences in the fine structure of the alveolar wall between the two groups. The prominent changes of the fine structure in the alveolar wall of the emphysematous lung are as follows: (1) increased proportion of interstitial tissue, (2) diminished number of capillaries, (3) thickening of the capillary endothelium, (4) narrowing of the capillary lumen.

Disturbance of diffusion in the emphysematous lung is demonstrated by the tests for respiratory functions^{1,4)}. Our findings indicate this to be due to the diminished capillary bed and the thickening of the "blood-air-barrier" in the emphysematous lung. The increase in resistance to blood flow in the pulmonary blood vessels in the emphysematous lung^{2,4)} is presumed to be caused by the diminishing of the capillary bed and the narrowing of the capillary bed and the narrowing of the capillary lumen.

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